

SAFETY SUBSTANTIATION REPORTS FOR THE WWER-440 UNITS OF KOZLODUY NUCLEAR POWER PLANT

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1. INTRODUCTION

In the Republic of Bulgaria there are 6 nuclear power units with WWER type reactors in operation. Units 1 to 4 of the Kozloduy Nuclear Power Plant (NPP) are equipped with WWER-440 reactors built to earlier standards. The existing norms and regulations at that time did not contain a comprehensive set of safety analysis as it is adopted nowadays.

A common deficiency of the safety analysis reports of these units is that they have been developed according to outdated normative requirements. Development of new safety substantiation reports, specific for each unit is in progress, in accordance with the existing international practices in the developed countries.

Further in the paper are discussed the regulatory requirements for format and content of WWER-440 unit's safety analysis reports (SARs) as well as the efforts and the progress of the Operating organisation to develop and upgrade the existing safety reports to comply with the contemporary understanding.

2. LEGISLATIVE BASIS

According to the Convention on Nuclear Safety [1] a comprehensive and systematic safety assessment of the nuclear power plants should be performed by the Operating organization. The assessment should reflect the unit's current safety status and has to be periodically updated taking into account the operating experience of the unit and any new information significant to safety [2].

In compliance with the international conventions the Bulgarian national nuclear legislation – the Act on the Use of Atomic Energy for Peaceful Purposes [3] and the

relevant CUAEPP Regulations require as well safety analysis report to be developed and approved by the Regulatory authority prior to the unit operation.

Regulation No.5 [4] stipulates the structure and content of safety substantiation reports at the various licensing stages. The site selection is justified in a reduced scope safety report that forms the relevant design basis of the nuclear installation based on analysis and assessment of the site characteristics. The safety of the design is described in a preliminary safety substantiation report (PSSR). The final report for safety substantiation (FSSR) takes into consideration the results from the construction and commissioning of the nuclear installation. The analysis and assessment of a spectrum of initiating events and their consequences are part of the PSSR and the FSSR. The spectrum of initiating events is determined on the base of probabilistic safety analysis.

3. STATUS OF DEVELOPMENT OF SSR

The original safety reports on the design of Kozloduy units 1-4 are developed in the 70's and 80's in a limited volume in comparison to what we expect today. They do not correspond at all to some of the requirements for demonstration of safety applied in the western countries. In the recent years the operating organisation has made considerable efforts towards the safety improvement of the units. Specific upgrading measures are being implemented there upon their safety justifications had been approved by the Regulatory body. Thus the consistency of the existing safety reports appears to be challenged and the need a systematic approach to be applied come up.

In 1997 the Inspectorate on Safe Use of Atomic Energy (ISUAE) by the means of prescription requested the Operating organisation to perform comprehensive and systematic assessment of the current safety status of these units.

In 1998 "Requirements for Structure and Contents of the Safety Substantiation Report of units 3 and 4" with WWER-440 type 230 reactors [6] had been developed by west European and Bulgarian experts in the framework of a PHARE project. The document contains detailed recommendations towards the assessment methodology, safety justification and the structure and content of the report. Some of the most essential to the safety substantiation aspects are as follows:

- Description of the current status of the units and existing practice for management of safety and operation;

- Review of the operational experience including analysis of tests results, operational events, modifications, radiological effects and processes of ageing of the materials;
- Analysis of accidents and transients;
- Identification of non-compliance with standards and issues arising from the safety analysis;
- Evaluation of current safety and future improvements.

The Safety Substantiation Reports for units 1-4, version “0” have been developed by the Operating organisation in consideration of the available safety documentation, the CUAEPP requirements and relevant international recommendations as well.

In 1999 the Operator had implemented the following steps of the elaboration process:

- Version “0” of the Reports had been submitted for review at the Regulatory body headquarters.
- In addition to the regulatory review the Operator had performed its own expertise on this draft. It was identified a need of implementation of large number of additional analyses to complement these ones in the existing safety reports and those that are performed for justification of safety upgrading measures.
- The deficiencies of this version had been clearly defined and the development of the next version “1” was assigned by the Operating organisation.

The current status of SAR development could be summarised in the following activities that are realised or in process of realisation according to the Implementation plan for the year 2000:

- The first version of the Safety Substantiation Reports for units 1-4 has been elaborated by an Operator’s contractor and adopted by an expert commission at Kozloduy NPP. Thus the need of additional analyses to be performed for the last version has been assessed.
- Till the end of the 3rd quarter of 2000 the Reports have been submitted volume by volume for regulatory review according to preliminarily agreed schedule. This procedure is requested by the Regulatory body in order to improve the efficiency of the work both of the development and the regulatory review teams and also to be achieved better co-ordination of the project.
- In process is development of Terms of Reference for elaboration of the last versions of the substantiation reports – the Safety Analysis Reports. This document will reflect the comments obtained from the internal NPP expert commission and have to consider as well the comments given by the regulatory review. Prioritisation of the

implementation of complementary deterministic and probabilistic safety analyses is being established.

4. PLANS FOR IMPLEMENTATION OF SARs

A Program for development and implementation of SARs for units 1-4 of Kozloduy NPP is being proposed by the utility [8]. The objectives of the Program are to be defined the stages of FSAR development based on the safety substantiation reports and also to establish activities for maintaining the FSAR in correspondence to the actual plant configuration. Further are explained the stages of FSAR development, implementation and maintenance.

4.1. Stage 1. Evaluation of the already developed safety substantiation reports and preparation of terms of reference for the FSAR

There are three groups of activities that are included in this stage. First of all the safety substantiation reports of units 1-4 will be assessed by an independent Bulgarian organization towards the relevant plant and regulatory requirements and also with respect to the results of the recent analyses performed. On that base terms of reference for the final edition of SARs is going to be prepared for approval.

The second provision is to be adopted a common methodology for transient and accident analyses that are going to be complemented to the final SAR. For that purpose the utility is going to develop an approach based on the IAEA guidelines [5], CUAPEPP norms and regulations [4] as well as the experience of other NPPs with WWER-440 type reactors. The analysis methodology will be submitted to the Regulatory body for approval.

The third issue foreseen to be preformed at the first stage is approval of the terms of reference for the FSAR by the utility expert commission and after that – by the Regulatory authority.

The deadline for completion of stage 1 is the end 2000-year.

4.2. Stage 2. Development of the SARs and their final approval

The realization of the development phase is planned to include the following activities:

- 4.2.1. Selection of Bulgarian organization for SAR development and signing of the contract

- 4.2.2. Implementation of additional analyses according to their prioritization
- 4.2.3. Completion of version “0” of the SARs
- 4.2.4. Assessment of the “0” version with participation of international expertise
- 4.2.5. Internal SAR review and acceptance by the utility expert commission
- 4.2.6. Submission to the Regulatory body for review
- 4.2.7. Preparation of the final edition of SAR considering the regulatory comments
- 4.2.8. Approval of FSAR by CUAEPP

The deadline for completion of stage 2 is the end 2001-year.

4.3. Stage 3. Development of Program for maintaining the FSARs in correspondence to the actual plant configuration

Once the SARs have been completed, necessity of long-term maintenance of the reports in actual conditions arises. Development of such programs is widely accepted practice among the nuclear operators even the period of updating varies from country to country. Nevertheless there is not especial regulatory requirement in Bulgaria for periodic updating of the safety reports, Kozloduy NPP plans to develop SAR maintenance program during the next year.

5. INTERNAL AND EXTERNAL EVENTS CONSIDERED IN THE SAR

The list of postulated initiating events (PIEs) for the WWER-440 units of Kozloduy NPP includes external and internal hazards. The minimum list of PIEs to be considered in the SARs has been defined by the Regulatory authority on the base of IAEA recommendations [5], Regulation No.5 of the CUAEPP [4] and all available information of possible PIEs. The utility has to carry out examination of the plant’s site characteristics and the plant system’s state using recognised systematic identification techniques to determine all the possible PIEs. Furthermore it is necessary to take into consideration any applicable experience of PIEs from other plants (especially, but not exclusively, from those of similar design), experience of safety assessments and research results.

The following general classification of the events has been made [6]:

- Incidents and design basis accidents. They are categorised according to their corresponding estimated frequencies. Higher radiological consequences are deemed tolerable for categories of lower estimated frequency. In any case, the successive barriers have to be maintained and the radiological consequences have to remain acceptable.

- Beyond design basis accidents. They are of very low likelihood but more severe than those considered explicitly in the design. For these accidents, complementary means (specific equipment or appropriated procedures) are used. The objective of these means is to ensure core cooling and to mitigate accident consequences. Moreover, the probability of any unacceptable consequences (uncovering of the core) has to be in the field of residual risk. These accidents include PIEs combined with failures of protection and PIEs and accident sequences of low frequency.

- Hypothetical severe accidents. The potential consequences of these accidents are more severe than those ones of design basis accidents. In these cases uncovering of the core and deterioration of the vessel are being postulated. Hence for this family of hypothetical accidents, the objective is to supervise or to recover the integrity of the confinement (3rd barrier) after an accident having lead to the deterioration of the 1st and the 2nd barriers. Possible approach is to categorise the different types of radioactive releases in “source terms” depending on the severity of the accident. The assumptions are the containment collapse with the complete fusion of the core. The source terms are used to define corrective measures in order to protect the public.

The frequency of the PIEs is being assessed on the basis of experience or system analysis, and each PIE should be assigned to one of the following frequency categories :

- PIEs of moderate frequency: these are PIEs, anyone of which may occur during a calendar year of the plant;
- infrequent PIEs: these are PIEs, anyone of which may occur during the lifetime of the plant;
- limiting PIEs: these are occurrences that are not expected to occur within the plant lifetime, but are postulated.

In the already developed versions of the safety substantiation report [7] of units 1-4, the initiating events are grouped into spectrums according to Appendix 1 of Guidelines IAEA-EBP-WWER-01 [5]. In addition some external hazards and site-related accidents is required to be included, such as:

- geologic and hydro-geologic related-accidents: earthquakes, external floods, dam failure;
- accidents due to industrial environment and communication ways: e.g. explosion, aircraft crash;
- accidents caused by the failure of an on-site equipment: flood, loss of cooling water or heat sink.

6. METHODOLOGY FOR ACCIDENT ANALYSIS

The general purpose of the accident analysis is to verify if the safety objectives are fulfilled by the functioning of the existing defences including the planned improvements (systems, components, procedures providing safety functions of prevention, control, protection) in all identified PIEs. The final safe state to be achieved is defined for the certain case. Conservative assumptions are used at all steps of such calculations of design basis accidents to show that the response of the plant and its safety systems to postulated events allow to meet safety targets and to guarantee that the final result in terms of radioactive release is acceptable [6].

Description of the approach used for the analyses is in a process of preparation by the utility. This document is going to be reviewed and approved by the Regulatory body if it demonstrates proper application of justified methodology, assumptions, acceptance criteria, rules, aggravating event, protection of equipment or components and the measures taken in order to ensure the safety of the unit. Equipment credited in the analysis should be of an appropriate safety class, and it must be analysed in system analysis. Human actions credited need to be based on procedures for operation and for accident conditions.

7. INTERRELATION OF PROBABILISTIC SAFETY ANALYSIS AND SAR

The examination of the balance of the safety concept of the entire plant and determination of the total frequency of not-controlled plant states is performed by a probabilistic safety analysis (PSA).

The results of the PSA are used to supplement the deterministic assessment of the plant's safety status and its operational safety and are referred to for the determination of the necessity and urgency of safety improvements.

The technical safety objective used is to apply accident prevention and mitigation measures in such a way that overall risk is very low and no accident sequence (of low or high probability) contributes to risk in a way that is excessive in comparison with other sequences.

Results of probabilistic studies are presented as supporting evidence, without overriding concerns about deterministic or qualitative engineering issues. Producing of

probabilistic assessments is of value in establishing the completeness of the list of internal and external initiating events and the defences that are most important in preventing accidents or protecting from the consequences of accidents [6].

8. CONCLUSIONS

As for any plant built to earlier standards, there are some deficiencies discovered against the current standards. In order to support a justification for the unit operation, the effects of each deficiency should be studied and analyzed to be determined their implication for defense in depth.

In addition to the permanent supervision of NPP operation by the Regulatory Authority, the current safety status of the units should be demonstrated in a comprehensive way.

REFERENCE

- [1] Convention on Nuclear Safety, Vienna, 1994
- [2] National Report of the Republic of Bulgaria on Implementation of the Convention on Nuclear Safety, Sofia, 1998
- [3] Act on the Use of Atomic Energy for Peaceful Purposes, Sofia, 1995
- [4] Regulation No. 5 on Issuing of Licenses for the Use of Atomic Energy, Sofia, 1993
- [5] Guidelines for Accident Analysis of WWER Nuclear Power Plants, IAEA-EBP-WWER-01, 1995
- [6] Requirements for Structure and Contents of the Safety Substantiation Reports of units 3 and 4 of Kozloduy NPP, Riskaudit, 1998
- [7] Отчет за обосновка на безопасността на блокове 1 до 4 в АЕЦ “Козлодуй”, Версия 1, Риск Инженеринг ООД, РИ/Д-155, 2000
- [8] Програма за дейностите по допълване на ООБ и развитието му в ТОБ на блокове 1-4, Проект, АЕЦ “Козлодуй”, 2000